JAN 20 1964

6p

[redacted] * AFSS-1

[redacted]

(NASA TMX54530)

A Note on the Atmospheric Composition of Venus

Double code

S. I. Rasool* (New York U.) 1719632

Jan. 1964 6p refs Submitted for Publication

Goddard Institute for Space Studies
National Aeronautics and Space Administration
New York, New York

1605781

and

Department of Meteorology
New York University

*NAS-NRC Senior Research Associate with NASA

Submitted to Science, January 1964

[redacted]

Recent evidence regarding the structure of the atmosphere of Venus indicates that the total surface pressure is at least 10 atm.[(1),(2)] and may be as high as several hundred atm.[(3),(4)]

Cameron[(3)] has attempted to account for the high surface pressure on Venus by postulating that the evolution of the atmospheres of the Earth and Venus has taken place by entirely different processes; the Venus atmosphere is a remnant of the primitive solar nebula, while the Earth lost its atmosphere during the initial rotational instability which led to the separation of the moon from the Earth.

There is, however, one aspect of this hypothesis which presents an immediate difficulty. Carbon dioxide is a known constituent of the Venus atmosphere. Spinrad[(2)] has estimated the abundance of CO_2 by spectroscopic methods, and finds that it is approximately 4% by mass of the total atmosphere. As N_2 is not detectable by classical spectroscopic techniques, and is present in abundance in the terrestrial atmosphere, it is usually assumed that the remaining 96% of the Venus atmosphere is made up primarily of N_2, i.e., the N_2/CO_2 ratio is 25:1[(2),(3)] However, if, as hypothesised by Cameron, the atmosphere of Venus were a remnant of the solar nebula, the atmospheric composition should reflect the

[redacted]

relative solar abundances of the elements. These have been recently compiled in a revised form[5] and indicate a N_2/CO_2 ratio of 1:12 (Table I). This result is in strong disagreement with the abundance ratio quoted above.

A result obtained by Chamberlain[6] may have a bearing on this problem. Chamberlain has pointed out that the presence of a considerable amount of CO_2 in a planetary atmosphere reduces the exospheric temperature of the planet because of radiative cooling by CO in the upper atmosphere. Chamberlain has applied his calculations to the planet Mars and finds that the CO cooling acts as a thermostat and keeps the temperature of the escape level of the Martian atmosphere from exceeding 1100 ^{o}K. For this reason, the gravitational escape of light gases from Mars probably takes place at a much slower rate than was previously assumed.

Due to the considerable abundance of CO_2 in the Venus atmosphere, it is possible that a similar cooling mechanism occurs in the upper atmosphere and reduces the rate of escape of light gases. A calculation of the escape time, from the method described by Spitzer[7], indicates that if the exospheric temperature of Venus has remained at 1100 ^{o}K, the time of escape of helium from Venus will be $\sim 10^{11}$ years. As the age of the planets is $\sim 4.5 \times 10^9$ years, helium would be retained on Venus and would then be the dominant atmospheric constituent, rather than nitrogen.

If this is the case, the atmosphere of Venus should have a composition consistent with the solar abundances of the elements. Table I shows the composition of the atmosphere derived in this way. The table is based on the assumptions that (1) all hydrogen has completely escaped, including that in the form of NH_3, CH_4 and H_2O, (2) the oxygen available for the atmosphere has been depleted by that amount which would be required to form metal oxides and silicates, (3) only that much carbon is included in the atmosphere which will combine with the remaining oxygen to form CO_2, and (4) CO_2 has not been removed from the atmosphere by reactions with the crust of the planet.

TABLE I

Substance	% by Mass
He	94.23
CO_2	4.78
N_2	0.38
Ne	0.53
$A^{36} + A^{38}$	0.08

It may be noted that the CO_2/He ratio in Table I is close to Spinrad's estimate of a CO_2 abundance ratio of 4%.

Suess[8] has suggested that neon may be the dominant atmospheric constituent on Venus. It is interesting to note that according to Table I the Ne/CO_2 ratio is less by a factor of $\sim$ 100 than is predicted by Suess. The measurement of the rare gas abundances on Venus, by local sampling carried out from planetary probes, will provide a clear discrimination among these hypotheses.

REFERENCES

(1) Kaplan, L. D., "A preliminary model of the Venus atmosphere," Jet Propulsion Laboratory Tech. Rep. No. 32-379 (1962).

(2) Spinrad, H., "Spectroscopic temperature and pressure measurements in the Venus atmosphere," Publ. Astron. Soc. Pacific, 74, pp. 187-201 (1962).

(3) Cameron, A. G. W., "The origin of the atmospheres of Venus and the Earth," Icarus, 2, 249 (1963).

(4) Thaddeus, P., private communication.

(5) Cameron, A. G. W., Revised table of solar abundances of the elements, privately circulated, November 26, 1963.

(6) Chamberlain, J. W., "Upper atmospheres of the planets," Astrophys. J. 136, 582, 1962.

(7) Spitzer, L. Jr., "The terrestrial atmosphere above 300 km," in Atmospheres of the Earth and Planets, edited by G. P. Kuiper (University of Chicago Press, Chicago), p. 211 (1952).

(8) Suess, H. E., "Remarks concerning the chemical composition of the atmosphere of Venus," Z. Naturforschg. (in press).